Topic- Fiber Optics

BY -
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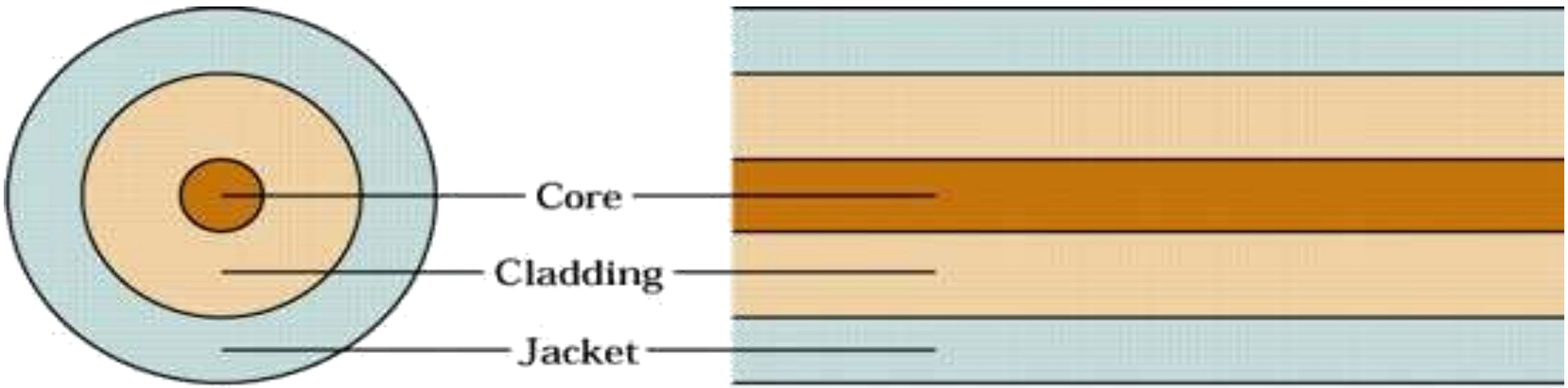
Introduction

- An optical fiber is essentially a waveguide for light.
- It consists of a **core** and **cladding** that surrounds the core.
- The **index of refraction** of the cladding is less than that of the core, causing rays of light leaving the core to be refracted back into the core.
- A light-emitting diode (LED) or **laser diode** (LD) can be used for the source.
- Advantages of optical fiber include:
  - Greater bandwidth than copper
  - Lower loss
  - Immunity to **crosstalk**
  - No electrical hazard

Optical Fiber & Communications System



(a) Fiber cross section

(b) System

Optical Fiber

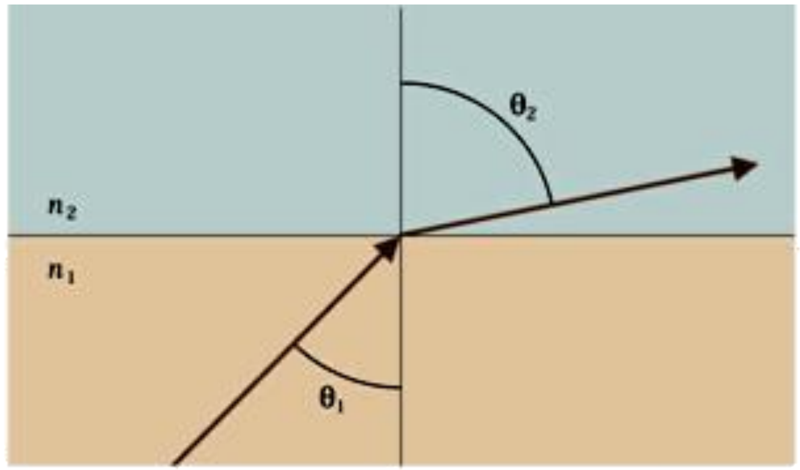
- Optical fiber is made from thin strands of either glass or plastic
- It has little mechanical strength, so it must be enclosed in a protective jacket
- Often, two or more fibers are enclosed in the same cable for increased bandwidth and redundancy in case one of the fibers breaks
- It is also easier to build a full-duplex system using two fibers, one for transmission in each direction

Total Internal Reflection

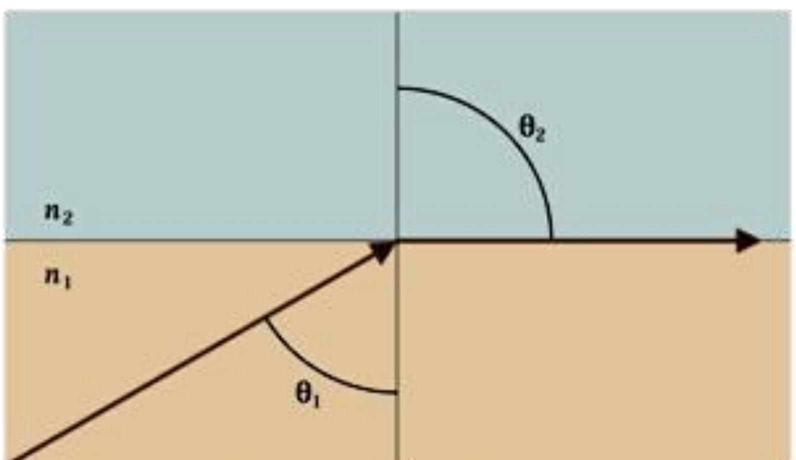
- Optical fibers work on the principle of **total internal reflection**
- With light, the refractive index is listed
- The **angle of refraction** at the interface between two media is governed by Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

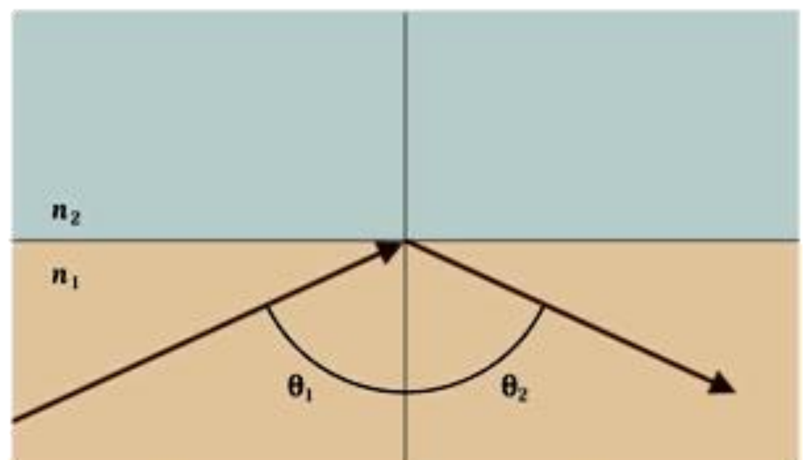
Refraction & Total Internal Reflection



(a) Angle of incidence less than critical angle



(b) Angle of incidence equal to critical angle



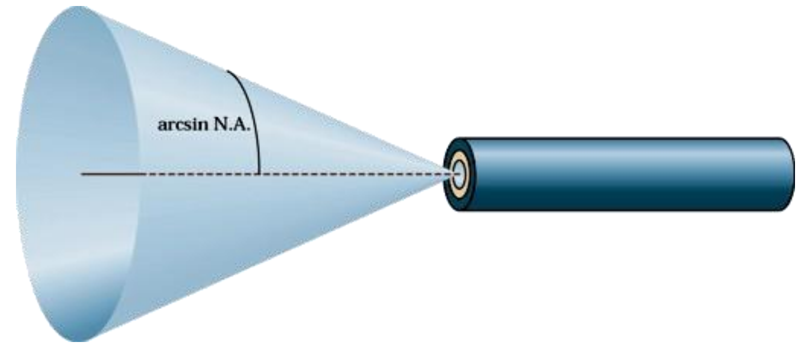
(c) Angle of incidence greater than critical angle

Numerical Aperture

- The **numerical aperture** of the fiber is closely related to the critical angle and is often used in the specification for optical fiber and the components that work with it
- The numerical aperture is given by the formula:

$$N.A. = \sqrt{n_1^2 - n_2^2}$$

- The **angle of acceptance** is twice that given by the numerical aperture

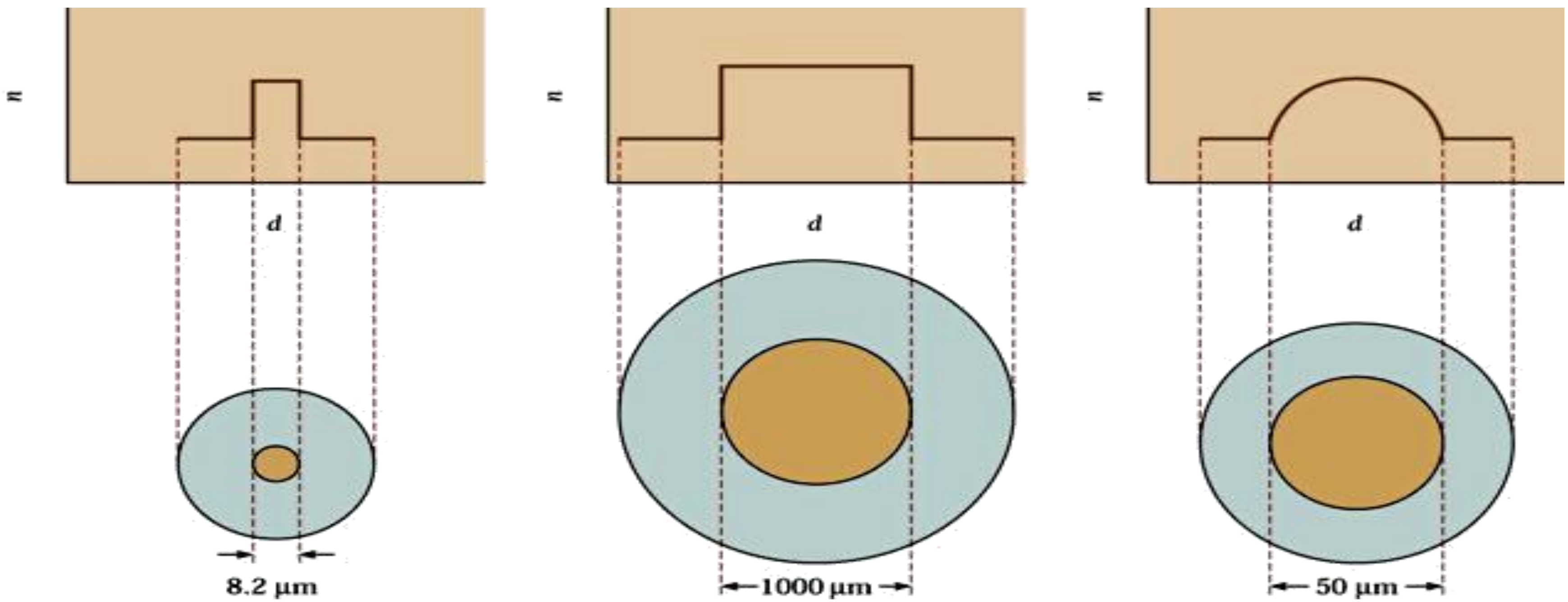


Modes and Materials

- Since optical fiber is a waveguide, light can propagate in a number of modes
- If a fiber is of large diameter, light entering at different angles will excite different modes while narrow fiber may only excite one mode
- Multimode propagation will cause **dispersion**, which results in the spreading of pulses and limits the usable bandwidth
- **Single-mode** fiber has much less dispersion but is more expensive to produce. Its small size, together with the fact that its numerical aperture is smaller than that of **multimode** fiber, makes it more difficult to couple to light sources

Types of Fiber

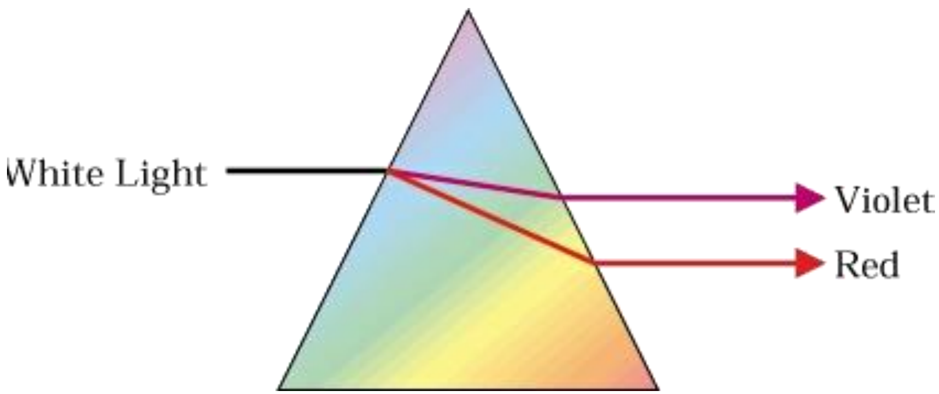
- Both types of fiber described earlier are known as **step-index** fibers because the index of refraction changes radically between the core and the cladding
- **Graded-index** fiber is a compromise multimode fiber, but the index of refraction gradually decreases away from the center of the core
- Graded-index fiber has less dispersion than a multimode step-index fiber

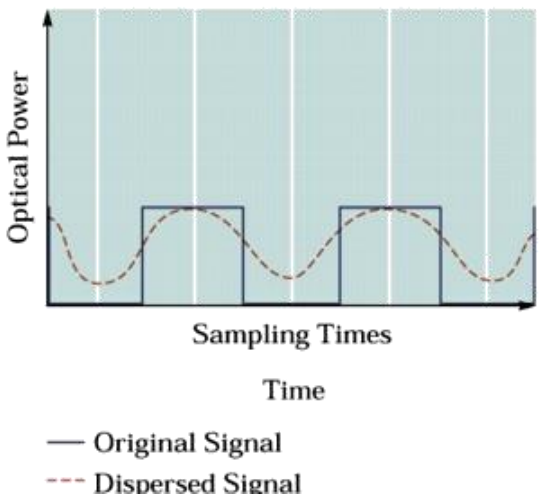


Dispersion

- Dispersion in fiber optics results from the fact that in multimode propagation, the signal travels faster in some modes than it would in others
- Single-mode fibers are relatively free from dispersion except for *intramodal dispersion*
- Graded-index fibers reduce dispersion by taking advantage of higher-order modes
- One form of intramodal dispersion is called *material dispersion* because it depends upon the material of the core
- Another form of dispersion is called *waveguide dispersion*
- Dispersion increases with the bandwidth of the light source

Examples of Dispersion

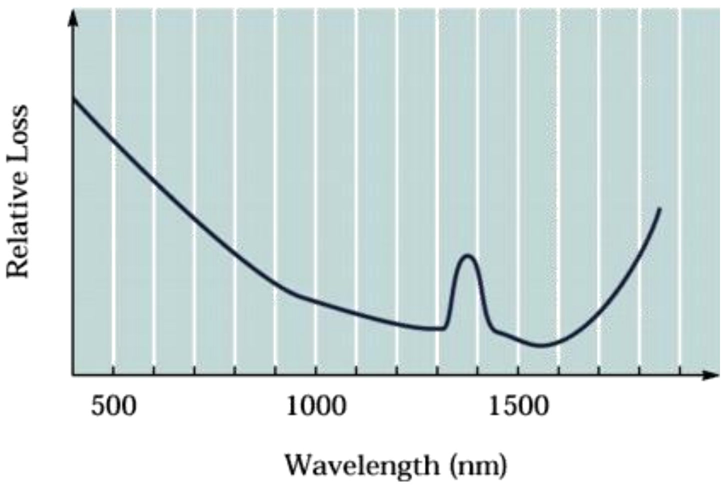


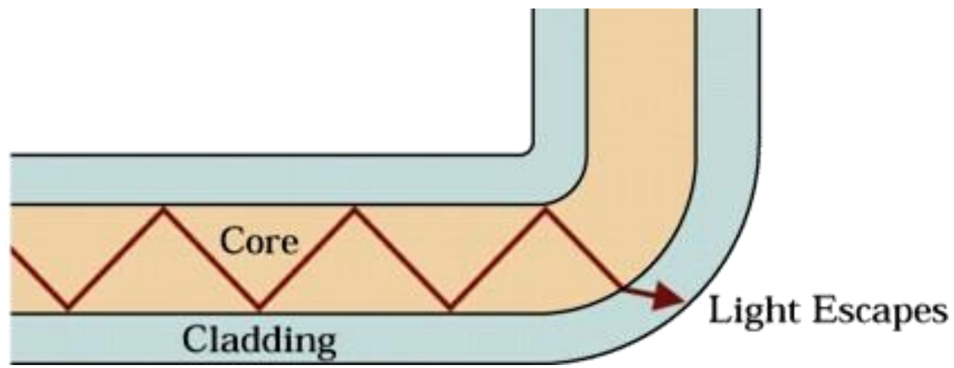


Losses

- Losses in optical fiber result from attenuation in the material itself and from scattering, which causes some light to strike the cladding at less than the critical angle
- Bending the optical fiber too sharply can also cause losses by causing some of the light to meet the cladding at less than the critical angle
- Losses vary greatly depending upon the type of fiber
  - Plastic fiber may have losses of several hundred dB per kilometer
  - Graded-index multimode glass fiber has a loss of about 2–4 dB per kilometer
  - Single-mode fiber has a loss of 0.4 dB/km or less

Types of Losses

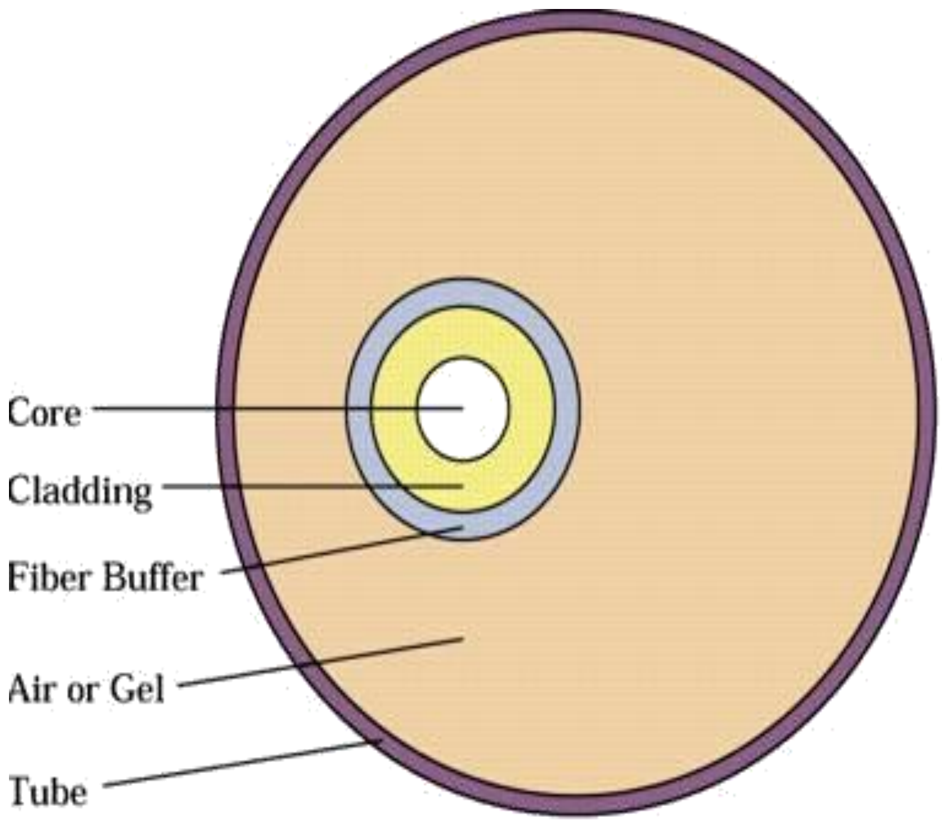




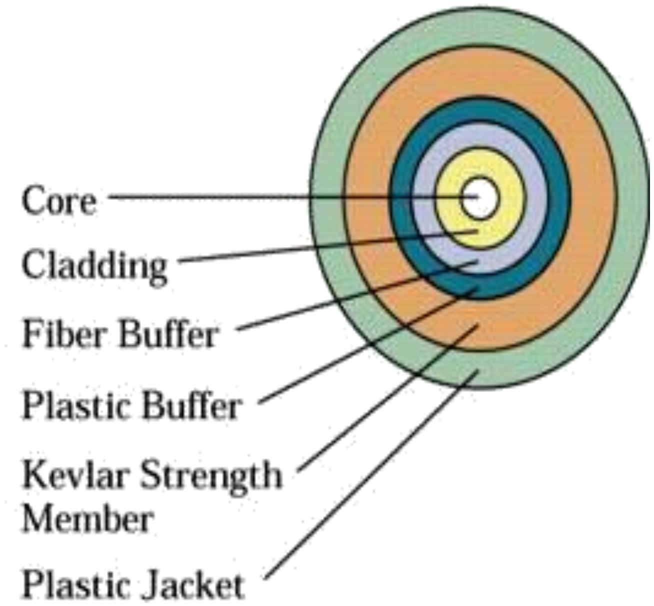
Fiber-Optic Cables

- There are two basic types of fiber-optic cable
  - The difference is whether the fiber is free to move inside a tube with a diameter much larger than the fiber or is inside a relatively tight-fitting jacket
- They are referred to as *loose-tube* and *tight-buffer* cables
- Both methods of construction have advantages
  - Loose-tube cables—all the stress of cable pulling is taken up by the cable's strength members and the fiber is free to expand and contract with temperature
  - Tight-buffer cables are cheaper and generally easier to use

Fiber-Optic Cable Construction



(a) Loose-tube construction



(b) Tight-buffer construction

Thank you